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REVISED ECONOMIC INVENTORY PROCEDURE (EIP) TABLES FOR DARCOM DE--ETC(U)
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REVISED ECONOMIC INVENTORY PROCEDURE (EIP) TABLES FOR DARCOM DEPOTS

U.S. ARMY
INVENTORY
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OFFICE

September 1977

ROOM 800
U.S. CUSTOM HOUSE
2nd and Chestnut Streets
Philadelphia Pa. 19106

REVISED ECONOMIC INVENTORY PROCEDURE (EIP) TABLES FOR DARCOM DEPOTS

FINAL REPORT

BY

ROBERT L. DEEMER

SEPTEMBER 1977

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US ARMY INVENTORY RESEARCH OFFICE
US ARMY LOGISTICS MANAGEMENT CENTER
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The EIP tables of AR 710-2 are revised. The Operating Level is revised to reflect current (December 1975) holding and ordering costs. The reorder point is revised to reflect a new and better methodology that considers both demand and order-and-ship time variability and achieves inventory targets commensurate with budgetary limits. Revised stockage criteria tables are developed by means of a mathematical model that produce more economic stockage decisions.

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(Abstract continued)

The results presented are only applicable to DARCOM depots; however, with modifications the procedures could be applied to other levels of the Army retail supply system.

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SUMMARY

1. Background

The Economic Inventory Procedure (EIP) Tables used in Figure 3-9, AR 710-2 [2] originated in the late 1950's. The costs necessary to derive the values in Figure 3-9 were obtained from information dating back to that time. They have not been updated since.

In August 1974, the United States Army Materiel Development and Readiness Command, DARCOM, (at that time AMC, Army Materiel Command) requested the Inventory Research Office, IRO, to update the costs and the Operating Level portion of those tables for use by the DARCOM depots. Upon completion of that task (December 1975, [4]), DARCOM requested IRO to update the remainder of Figure 3-9, namely, the reorder point and the stockage policy tables [1].

The reorder point and stockage policy tables were modified for use by DARCOM depot Installation Supply Account (ISA) activities using results from previous IRO work. This previous work included research on the reorder point and the demand variance prediction for the wholesale level of supply [6 and 10] and at the overseas theatre level of supply [3]. Other results used in this project include the economic stockage policy model developed by Orr and Kaplan [13] and the order-and-ship time distribution work by Kruse [11].

2. Purpose and Objectives

The purpose of this study is to revise Table B (Operating Level), Table C (Reorder Point) and Table A (Stockage Policy) of Figure 3-9, AR 710-2 [2] for application to ISA activities.

The Operating Level and reorder point refer to the depth of stockage and the stockage policy refers to the range of items to be stocked. The EIP tables of AR 710-2 presently enable the user to make such decisions.

3. Scope and Methods

The Operating Level (OL) was calculated based on the holding and ordering costs found applicable to the ISA functions at the DARCOM

depots [4]. These costs were then applied in the Wilson square root formula [9] to find the OL. This OL was then input to the safety level (SL) calculations which minimize the sum of holding, ordering and shortage costs. The model used was the same model used at the Army wholesale level of supply.

These OL's and SL's were then input to the economic stockage model to determine if it is more economical to stock or not stock the item. Decisions were based solely on economic and supply performance considerations. No essentiality measures were used in any of the calculations. Thus, augmentation of the stockage list may be required to add those items deemed to be highly essential but whose stockage cannot be justified on economic grounds.

4. Conclusions and Findings

Using the updated holding and ordering* costs [4] and the Wilson square root formula, the derived operating level table is as follows (revised Table B, Figure 3-9, AR 710-2):

TABLE 1

OPERATING LEVEL

Annual Dollar Demand	Operating Level (Months)
Less Than or Equal to 100	12
100.01 - 300	9
300.01 - 900	6
900.01 - 2000	4
2000.01 - 4000	3
4000.01 - 10000	2
Greater Than 10000	1

The reorder point tables were calculated using a model similar to that used for the wholesale level of supply (see DoDI 4140.39 [8]). In

*The ordering cost presented in [4] was modified to include a $2.60 cost of processing a requisition at the next higher level of supply.

addition, the model used here accounts for OST variability via an empirical histogram. The requisition short cost was set so that the inventory dollars of the revised computations equaled (approximately) the inventory dollars under the current system at New Cumberland Army Depot. The reorder point tables derived are in Table 2 (revised Table C, Figure 3-9, AR 710-2). The rows of the table represent the annual dollar value of demand (units) and the columns represent the frequency with which requisitions are placed for ISA stock.

There are a total of six revised reorder point tables. They are for forecasted order-and-ship time (OST) values of 15, 30, 45, 60, 75 and 90 days. Only one table is shown in Table 2, OST value of 15 days. The complete set of tables (six OST values) is presented in Section 2.7.

Using Tables 1 and 2 and the basic stockage model of Orr and Kaplan [13], a stockage policy table is shown in Table 3 (revised Table A, Figure 3-9, AR 710-2). The rows once again represent the annual dollar value of demand (units) and the columns represent the addition (A) and retention (R) criteria for the six OST values.

Again, there are six stockage policy tables which would be implemented and they are presented in complete form in Section 3.3. Only the one table (OST of 15 days) is shown here for exposition purposes.

Are these revised results better cost/effectively than the present tables? Orr [12] developed a method of projecting statistics for a given stockage criteria/depth of stockage policy. The projected cost/effectiveness of the two procedures is shown here:

	Present	Revised
\$ Inventory	\$768,478	\$754,969
Availability	.72	.76

where \$ Inventory represents the dollars spent on average inventory on-hand per year and availability represents the fraction of all requisitions (ASL and non-ASL) satisfied from stock on-hand. These projections indicate that the proposed procedure spends approximately the same amount of money (actually 1.7% less) and is more effective at picking which items to stock and how much of each item should be stocked since the availability is greater under the revised tables.

TABLE 2

ROP (MONTHS) OST - 15 DAYS

$ AYD	ANNUAL FREQUENCY 1	2	3	4-9	10-15	16-40	> 40
≤ 200	2.8	5.5	5.5	5.5	5.5	5.5	5.5
200.01 - 500	.5	.5	2.2	5.1	4.6	3.6	3.5
500.01 - 1000	.5	.5	.5	2.3	3.1	2.8	2.6
1000.01 - 5000	.5	.5	.5	.5	1.3	1.9	1.9
5000.01 - 10000	.5	.5	.5	.5	.5	1	1.3
> 10000	.5	.5	.5	.5	.5	.5	.5

TABLE 3

STOCKAGE POLICY

OST = 15 DAYS

$ AYD	A	R
≤ 200	3	1
200.01 - 800	4	2
800.01 - 3000	5	2
3000.01 - 10000	9	5
10000.01 - 15000	12	7
> 15000	12	7

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CHAPTER I

OPERATING LEVEL

1.1 Model

The original Operating Level (OL) table (Table B, Figure 3-9, AR 710-2) was computed based on the Wilson square root formula [9] using the holding and ordering costs which were determined in the late 1950's by Harbridge House.*

The Wilson formulation balances the cost of ordering stock from a supplier. In December 1975 the holding and ordering costs were updated for the DARCOM depot Installation Supply Account, ISA [4]. The ordering cost in [4] did not include the requisition processing cost at the National Inventory Control Point, NICP. This requisition processing cost was derived for Army NICP's in a DSA report [7]. This DSA derived cost ($2.67) was added to the ordering cost developed in [4] ($18.40) for a total cost of $21. This $21 figure is used throughout the calculations in this report (see Appendix A for a summary of these DSA costs).

The Wilson formula for the OL is given by:

$$OL = \sqrt{\frac{2(D)(O)}{(H)(U)}}$$

where D = average yearly demand (quantity)

O = ordering cost ($21 per order)

H = yearly holding cost rate (.25)

U = unit price of item

By dividing by the average monthly demand (D/12), the Operating Level is defined in months as a function of the annual dollars of demand, i.e.,

$$OL\text{ (months)} = \frac{12}{D}\sqrt{\frac{2(D)(O)}{H(U)}} = \sqrt{\frac{288(O)}{H(UD)}}$$

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*"Economic Inventory Policy Interim Report #1, Test of Station Inventories," Harbridge House, Boston, MA, 1959.

Using the updated holding and ordering costs shown above:

$$OL(\text{months}) = \frac{155.54}{\sqrt{UD}} \qquad (1)$$

1.2 Computations

Table B, Figure 3-9, AR 710-2 is an approximation to the Wilson formula. This approximation was accomplished by grouping the annual dollar demand into four intervals. However, using the revised holding and ordering costs, these particular intervals may no longer be the best ones to use. Hence, smaller intervals were used initially to find out where the breaks would more naturally occur. It is evident that any number of interval breakdowns could be used.

Smaller intervals may not be needed. Where should these breaks occur? Two options were evaluated which were subjective attempts to balance brevity and understanding for the user against the cost of the option.

The present EIP OL table has a 12 month maximum OL and a one month minimum OL. These two constraints are maintained in the approximations.

The total cost, the sum of the holding and ordering cost is

$$TC = H \frac{(OL)}{2} U + O \frac{D}{(OL)} \qquad (2)$$

where TC = the total yearly cost

OL = the Operating Level quantity

If the holding cost, the first term, is multiplied by D/D and recognizing that D/OL is the frequency of ordering, the total cost can be written as a function of annual dollar demand and order frequency,

$$TC = H \frac{(OL)(U)(D)}{2(D)} + O \frac{D}{OL}$$

$$= \frac{H(UD)}{2f} + O\,f \qquad (3)$$

where f is the order frequency.

Table 4 (next page) represents the optimum values of expression (1) evaluated at different annual dollar of demand (UD) values. The months of supply for the optimum OL computation (MOS) is translated into a frequency of ordering (FREQ) and the cost (COST) is an evaluation of expression (3). The columns for option 1 and option 2 are the two alternatives evaluated based on approximations to the optimum values.

1.3 Results

The final version of the updated Operating Level table is:

TABLE 5

OPERATING LEVEL

Annual Dollar Demand	Operating Level (Months)
Less than or equal to 100	12
100.01 to 300	9
300.01 to 900	6
900.01 to 2000	4
2000.01 to 4000	3
4000.01 to 10000	2
Greater than 10000	1

Table 5 represents option 2 from Table 4, which was chosen because it meets the criteria of brevity and understanding at the lowest cost of any option considered.

TABLE 4

	OPTIMUM			OPTION 1			OPTION 2		
UD	FREQ	MOS	COST	FREQ	MOS	COST	FREQ	MOS	COST
100	.77	15.6	32.40	1	12	33.5	1	12	33.5
200	1.09	11.0	45.83	1.33	9	46.73	1.33	9	46.73
300	1.33	9.0	56.13	1.33	9	56.13	1.33	9	56.13
400	1.54	7.8	64.81	2	6	67.00	2	6	67.00
500	1.71	7.0	72.46	2	6	73.25	2	6	73.25
600	1.90	6.3	79.37	2	6	79.50	2	6	79.50
700	2.03	5.9	85.73	2	6	85.75	2	6	85.75
800	2.18	5.5	91.65	2	6	92.00	2	6	92.00
900	2.31	5.2	97.21	3	4	100.50	2	6	98.25
1000	2.45	4.9	102.47	3	4	104.67	3	4	104.67
2000	3.43	3.5	144.91	4	3	146.50	3	4	146.33
3000	4.29	2.8	177.50	4	3	177.75	4	3	177.75
4000	4.8	2.5	204.97	6	2	209.33	4	3	209.00
5000	5.45	2.2	229.13	6	2	230.17	6	2	230.17
6000	6	2	251.00	12	1	314.50	6	2	251.00
7000	6.32	1.9	271.17	12	1	324.92	6	2	271.83
8000	7.06	1.7	289.90	12	1	335.33	6	2	292.67
9000	7.5	1.6	307.50	12	1	345.75	6	2	313.50
10000	7.5	1.6	324.17	12	1	356.17	6	2	334.33
15000	9.23	1.3	396.97	12	1	408.25	12	1	408.25
TOTAL			3325.28			3587.70			3371.61

CHAPTER II

REORDER POINT

2.1 Safety Level Calculations

DoDI 4140.39 [8] directs the wholesale level of supply to use a specified objective in calculating the safety level. However, the directive leaves the specific calculation technique to the users. Deemer and Kruse [6] tested various models and found the negative binomial probability distribution gave best results for calculating safety levels for items with less than 20 units of demand per year and good results for other items.

In an earlier effort, Chern [3] worked on calculating safety levels for overseas inventory control points. These results indicated that the use of the negative binomial probability distribution gave good results at this level as well.

The methodology of DoDI 4140.39 is to minimize total cost, i.e., holding plus ordering plus shortage costs, for all items over a year. The shortage cost is a function of a requisition short cost, denoted by λ (this cost will be explained in the next section) and the time-weighted, essential - weighted requisitions short. The time-weighted requisition short (TWRS) measure recognizes not only that the supplier is out of stock but also how long the customer will have to wait until the item becomes available.

The essentiality is dropped from the performance measure because at the present time DoD has not approved of any way of measuring essentiality.

The wholesale model (DoDI 4140.39) is appropriate at the DARCOM depot level of supply as well. Therefore, the safety level model which is applied to the depot level is the wholesale model with appropriate parameter changes applicable to the DARCOM depot ISA.

2.2 Requisition Short Cost

The wholesale level model applies the same requisition short cost, λ, to every requisition on backorder for all items. This results in a different target availability for each item, where availability is defined as the percent of requisitions which can be satisfied from stock on-hand. The

question arises as to what the requisition short cost should be. The cost is difficult to identify in an absolute sense and, therefore, it is used as a control knob or implied cost rather than a direct cost. The λ value can control the safety level to give a predetermined level of performance or, conversely, can optimally allocate a given amount of stockage investment. An increase in λ increases safety level dollars because more importance is being attached to being out of stock. Likewise, a decrease in λ results in attaching less importance to being out of stock; hence, more backorders will be tolerated and thus a smaller safety level can be used.

The safety level calculations used here are based on a λ value which yields approximately the same inventory dollars as the present tables yield for the projected New Cumberland Army Depot (NCAD) Authorized Stockage List (ASL) items. The safety level is computed from the NCAD data using six different values for the forecasted order and ship time. The reorder point (ROP) is defined as the sum of the safety level (SL) and the order-and-ship time (OST); hence,

$$ROP = SL + OST$$

The λ value so derived is \$1200 per requisition per year.

2.3 Variance of Demand

In 1972 Chern [3] completed a study which evaluated data for computation of safety levels at overseas inventory control centers. As a part of that study an empirical estimation of variance of demand was made. Two years later Kaplan [10] completed a study which found a variance estimator for the wholesale level of supply. Both methods estimated the percent forecast error as a function of demand frequency and annual dollar demand. The percent forecast errors from both of these studies were very similar, i.e., for a given demand frequency and annual dollar demand, the percent forecast errors were approximately the same.

Since the results were roughly the same for two different levels of supply, the assumption was made that these values were also typical of the

depot ISA level. Kaplan's [10] wholesale results were used in this work since these were more current values and probably reflect more reliable data due to the more sophisticated data collection techniques in use at the wholesale level.

Chern [3] also looked at the inclusion of the OST variability in the demand variability estimation. The results of that work showed that while demand variance was the predominant factor in the variance estimation, the OST variance could not be ignored since the safety levels did change when this factor was included in the variance. These results led to the inclusion of the OST variability into the overall demand variance calculation. Chern incorporated this OST variability by use of a formula for the variance of a dependent random variable (OST demand) which accounts for the variance of the dependent variable (OST) developed by Parzen [14]. (See Appendix B for the form of the this total variance expression.)

2.4 Stochastic Lead Times

Another method of accounting for variable lead times is developed by Hadley and Whitin [9]. Their method of accounting for stochastic lead times is to use conditional costs weighted by the probability of experiencing a given order-and-ship time, i.e.,

$$TC(R,Q) = \int_0^\infty TC(R,Q|t)g(t)dt \qquad (4)$$

where $TC(R,Q|t)$ is the total annual variable cost as a function of the reorder point, R, reorder quantity, Q, given a lead time, t, and g(t) is the density function of t. This method assumes orders do not cross. See Appendix B about this assumption.

The density function of the lead time, g(t), is approximated by an empirical histogram (see Kruse [11]). The present reorder point values of the EIP tables are derived for OST values of from 10 to 90 days in steps of 5 day intervals. A change of 5 days in the OST will not make all that much difference in the reorder point values. Hence, OST forecasted

values of 15 to 90 days in steps of 15 days were chosen as the target values. The Kruse histogram represents the probability of seeing a particular lead time for a given forecasted lead time. Figure 1 represents the histogram used to compare the revised reorder point tables with the present EIP forecasted cost/effectiveness.

Suppose the depot ISA technique forecasts an OST of 30 days. Figure 1 says that the actual observed OST for that particular item will be 7.5 days 4.9% of the time, 15 days 42% of the time, 30 days 37.6% of the time, 45 days 6.4% of the time, 60 days 2.4% of the time, etc.

Using the above histogram, expression (4) can now be written as:

$$TC(R,Q|\overline{OST}) = \sum_{t} TC(R,Q|t)h(t|\overline{OST}) \qquad (5)$$

where

$\overline{OST}$ = forecasted OST value

t = experienced OST value

$h(t|\overline{OST})$ = probability of experiencing an OST of t days given the forecasted OST value, $\overline{OST}$

Other parameters as in expression (4).

2.5 Sensitivity of OST Variability

A test was made of the sensitivity of the histogram. In actual practice the probabilities of observing a particular OST value may change for a given forecasted value. If this happens, how could the change be expected to effect the safety level values produced? Kruse's empirical histogram (Figure 1) and a subjectively derived histogram (yielding the same expected OST value) shown in Figure 2 are compared in Table 6.

The operating cost of Table 6 is a theoretical measure which takes into account some of the performance measures listed. The holding cost component of the operating cost is the cost of holding the requisition objective (*RO = ROP + OL*) in inventory for one year. The order cost is the cost of replenishing stocked items to meet objectives set forth in developing the *OL* and *ROP*. The variable removal cost is the turbulence

FIGURE 1

PROBABILITY OF OTHER THAN FORECASTED OST VALUES

FORECASTED	POSSIBLE OBSERVED OST											
OST	7.5	15	30	45	60	75	90	105	120	135	150	165*
15	.120	.712	.103	.031	.010	.005	.003	.003	.005	.002	.001	.006
30	.049	.420	.376	.064	.024	.017	.011	.005	.006	.008	.003	.015
45	.030	.353	.278	.124	.060	.036	.023	.018	.016	.010	.010	.041
60	.000	.149	.341	.245	.060	.052	.022	.018	.016	.022	.009	.067
75	.000	.000	.028	.350	.322	.090	.045	.040	.034	.017	.017	.056
90	.000	.000	.021	.229	.188	.125	.042	.083	.042	.042	.021	.208

*The last category is really greater than 150 and the actual OST value changes from row to row to allow the mean value of the observed OST values to be equal to the forecasted value.

FIGURE 2

SUBJECTIVE PROBABILITIES

FORECASTED OST	POSSIBLE OBSERVED OST 7.5	15	30	45	60	75	90	105	120	135	150	165
15	.15	.800	.041	.001	.001	.001	.001	.001	.001	.001	.001	.001
30	.017	.100	.800	.075	.001	.001	.001	.001	.001	.001	.001	.001
45	.010	.013	.100	.750	.120	.001	.001	.001	.001	.001	.001	.001
60	.001	.001	.008	.120	.750	.110	.005	.001	.001	.001	.001	.001
75	.001	.001	.001	.020	.130	.700	.120	.023	.001	.001	.001	.001
90	.001	.001	.001	.001	.017	.130	.700	.120	.026	.001	.001	.001

TABLE 6

COST/EFFECTIVENESS OF HISTOGRAM

	EMPIRICAL	SUBJECTIVE
Number of Items	5755	5752
Accommodation	.81	.81
Satisfaction	.95	.95
Availability	.76	.76
Turbulence	.19	.19
$RO	1,760,900	1,820,759
$Inventory	640,369	658,755
Operating Cost	523,759	539,837

Accommodation = expected fraction of all requisitions that are for ASL items

Satisfaction = expected fraction of ASL requisitions that are satisfied from stock on-hand

Availability = fraction of all requisitions satisfied from stock on-hand (same as initial fill)

Turbulence = fraction of items leaving the ASL in a year that started the year on the ASL

$RO = dollar value of the ROP plus the OL

$Inventory = dollar value of expected on-hand stock

Operating Cost = holding cost (of RO) + order cost + variable removal cost + fixed removal cost + cost of maintaining items on ASL

cost of the RO and the fixed removal cost is the turbulence cost of the items stocked. The cost of maintaining an item on the ASL is the cost involved in having an item on the ASL for one year.

The results shown in Table 6 indicate that for the same performance the subjective histogram spends 2.9% more on inventory than the empirical histogram. Since the subjective histogram appears to be an extreme case, i.e., almost as different from the empirical histogram as you can get and still keep the same expected OST, it looks like the cost/effectiveness is not very sensitive to changes in the histogram.

2.6 Results

Using the operating level calculated in Section 1.3, the λ value ($1200) discussed in Section 2.2, the six forecasted OST values and the histogram from Figure 1, the reorder point tables were computed. The results of the computations are shown in Tables 7 through 12. The reorder point is the safety level plus the order-and-ship time. The reorder points are in terms of months of supply based on the forecasted average yearly demand and $AYD represents the dollar value of annual demand. The column headings (Annual Frequency) represents the number of requisitions submitted per year for that item for ISA stock.

TABLE 7

ROP (MONTHS) OST - 15 Days

$AYD	ANNUAL FREQUENCY						
	1	2	3	4-9	10-15	16-40	> 40
≤ 200	2.8	5.5	5.5	5.5	5.5	5.5	5.5
200.01 - 500	.5	.5	2.2	5.1	4.6	3.6	3.5
500.01 - 1000	.5	.5	.5	2.3	3.1	2.8	2.6
1000.01 - 5000	.5	.5	.5	.5	1.3	1.9	1.9
5000.01 - 10000	.5	.5	.5	.5	.5	1	1.3
> 10000	.5	.5	.5	.5	.5	.5	.5

TABLE 8

ROP (MONTHS) OST - 30 Days

$AYD	ANNUAL FREQUENCY						
	1	2	3	4-9	10-15	16-40	> 40
≤ 200	6	6	6	6	6	6	6
200.01 - 500	1	4.7	6	6	6	6	6
500.01 - 1000	1	1	1.8	5.9	5.9	5.9	5.9
1000.01 - 5000	1	1	1	1.3	3.2	4.2	4
5000.01 - 10000	1	1	1	1	1.3	2.6	3
> 10000	1	1	1	1	1	1	1.1

TABLE 9

ROP (MONTHS) OST - 45 Days

$AYD	ANNUAL FREQUENCY 1	2	3	4-9	10-15	16-40	> 40
≤ 200	6.5	6.5	6.5	6.5	6.5	6.5	6.4
200.01 - 500	1.5	6.5	6.5	6.5	6.5	6.4	6.4
500.01 - 1000	1.5	1.5	3.9	6.5	6.5	6.4	6.4
1000.01 - 5000	1.5	1.5	1.5	2.1	4.9	5.9	6.1
5000.01 - 10000	1.5	1.5	1.5	1.5	2.1	3.7	4.5
> 10000	1.5	1.5	1.5	1.5	1.5	1.5	1.7

TABLE 10

ROP (MONTHS) OST - 60 Days

$AYD	1	2	3	4-9	10-15	16-40	> 40
	ANNUAL FREQUENCY						
≤ 200	7	7	7	7	7	7	7
200.01 - 500	2	7	7	7	7	6.9	6.9
500.01 - 1000	2	2.6	6	7	7	6.9	6.9
1000.01 - 5000	2	2	2	3.4	6.4	6.9	6.9
5000.01 - 10000	2	2	2	2	3.1	4.8	5.8
> 10000	2	2	2	2	2	2	2.4

TABLE 11

ROP (MONTHS) OST - 75 Days

$AYD	ANNUAL FREQUENCY 1	2	3	4-9	10-15	16-40	> 40
≤ 200	7.5	7.5	7.5	7.5	7.5	7.5	7.4
200.01 - 500	4.5	7.5	7.5	7.5	7.5	7.5	7.4
500.01 - 1000	2.5	5.5	7.5	7.5	7.5	7.5	7.5
1000.01 - 5000	2.5	2.5	2.9	5.1	7.5	7.5	7.5
5000.01 - 10000	2.5	2.5	2.5	2.5	4.4	6.2	7.1
> 10000	2.5	2.5	2.5	2.5	2.5	2.5	3.4

TABLE 12

ROP (MONTHS) OST - 90 Days

$AYD	ANNUAL FREQUENCY 1	2	3	4-9	10-15	16-40	> 40
≤ 200	8	8	8	8	8	8	7.9
200.01 - 500	7	8	8	8	8	8	8
500.01 - 1000	3	7.6	8	8	8	8	8
1000.01 - 5000	3	3	3.8	6.2	8	8	8
5000.01 - 10000	3	3	3	3	5.5	7.6	8
> 10000	3	3	3	3	3	3	4.2

CHAPTER III

ECONOMIC STOCKAGE POLICY

3.1 Basic Model

The previous chapters investigated the problem of depth of stockage of an item; when to order and how much to order. Now the problem of the range of stockage is pursued; which items should indeed be stocked.

The method used here to resolve the breadth of stockage problem was developed by Orr and Kaplan [13]. There were a few adjustments to their model in this work, mostly to the parameter values. A brief description of the model follows and the changes are explored in Appendix C.

The model finds the addition-retention (A-R) criteria which minimizes the expected cost. The A-R criteria define the number of yearly demands qualifying an item for the Authorized Stockage List, ASL, (addition) and the number of demands required to return the item on the ASL (retention). The expected cost is a discounted cost* assuming two states - on or off the ASL. The expected cost covers the cost of removing the items from the ASL, the cost of adding the item to the ASL, and the cost of leaving the item off the ASL. Associated with these costs are probabilities of being on and off the ASL which are functions of the A-R criteria, item demand characteristics, and the catalog demand distribution.

The various costs mentioned above depend on the previous results, viz, the Operating Level and the reorder point, if that item is to be stocked. Hence, if there is a change to one of the previous tables, there may be a corresponding change in the stockage table.

3.2 Cost Elements

The stockage policy is based on the evaluation of different costs. These costs and how they were derived are explained below.

The fixed cost of stocking an item was developed in a previous study [4] and is estimated as $7.73. The cost of adding an item to the ASL was set at $.01. This figure was used since the depot computer system

*See DoDI 7041.3 or AR 37-13 about this concept.

handles all the necessary work to restock an item and costs are very low. On the other hand, to remove an item from the ASL requires additional manual work since there may be stock still on hand and some action must be taken in regard to these items. This cost was set at $5 since it only costs $7.73 to fully maintain an item on the ASL. There is another aspect to the removal cost. The above cost represents a fixed cost, i.e., it is independent of how much the item costs. However, if the inventory on-hand represents a sizeable investment, there is more effort expended to keep the item in inventory and hence there is a variable removal cost associated with taking an item from the ASL. The cost of removing the item depends on the willingness of the issuing agency (NICP, DSA, etc.) to take the item back. If the issuing agency is low in its own stock, it is willing to take the item back. However, if the item is in long supply at the issuing agency then the agency is reluctant to take the item back. Analysis of stock supplies at TARCOM and TSARCOM indicated a 10% variable removal cost factor is indicative of the current situation at these two NICPs, where the 10% represents an approximate worth to the NICP because of the stock positions at the NICP.

The holding cost rate is the rate at the DARCOM depots for holding Installation Supply Account (ISA) stock. The holding cost rate is .25 [4].

The order cost was also developed in [4] and is $18.40. This is the cost associated with placing an order at an NICP. However, there is a $2.67 cost per requisition at the NICP which represents the requisition processing cost (see [7] for details). Hence, an order cost of $21 was used.

Since most of the requisition processing at the depots is automated, the cost of processing requisitions for items (both stocked and unstocked items) is very small. The costs were estimated to be $.01. (The NICP cost involves some manual operations, e.g., technical data research, which were not included in the depot processing cost).

The cost associated with not being able to fill a requisition from a customer from stock on-hand, the requisition short cost, is set at the same cost as derived in the safety level calculations, $1200 per requisition

per year on backorder, or $100 per month.

3.3 Results

Using the Operating Level of Chapter I, the reorder point of Chapter II, and the cost parameters of the previous section, the derived stockage criteria are shown in Table 13. The rows in the table represent the dollar value of annual demand within the OST designation. The numbers themselves represent the number of requisitions needed to qualify the item for the ASL (A) and the number of requisitions needed to keep the item on the ASL(R).

TABLE 13

STOCKAGE CRITERIA

$AYD	OST = 15 Days A	OST = 15 Days R	OST = 30 Days A	OST = 30 Days R	OST = 45 Days A	OST = 45 Days R
≤ 200	3	1	2	1	2	1
200.01 - 800	4	2	3	1	3	1
800.01 - 3000	5	2	4	2	3	1
3000.01 - 10000	9	5	7	3	6	3
10000.01 - 15000	12	7	11	5	8	4
> 15000	12	7	12	6	11	6

$AYD	OST = 60 Days A	OST = 60 Days R	OST = 75 Days A	OST = 75 Days R	OST = 90 Days A	OST = 90 Days R
≤ 200	2	1	2	1	2	1
200.01 - 800	3	1	2	1	2	1
800.01 - 3000	3	1	3	1	3	1
3000.01 - 10000	6	3	5	3	5	3
10000.01 - 15000	8	4	7	4	7	4
> 15000	11	6	10	5	10	5

CHAPTER IV

COST-EFFECTIVENESS EVALUATION

4.1 Comparison

How does the revised stockage criteria (Table 13) compare to the present AR 710-2 criteria? Several performance measures and costs of each of the models are shown in Table 14.

So that a consistent comparison could be made, the "present" figures are not actual values observed at NCAD. The number of items stocked, accommodation and turbulence values are based on theoretical computations developed by Orr [12]. The values represent the theoretical results of applying Orr's formulas to all the items at NCAD for which data was available for the observed time period. The measures are explained in connection with Table 6 and will not be discussed here.

The revised model gives higher expected performance (availability) at a lower cost ($ inventory). Table 14 points out the significant difference between the two techniques. The revised method stocks more items but the items stocked are of lower cost than those stocked by the present technique (holding cost). In stocking more lower cost items there is a greater cost involved in maintaining items on the ASL as well as the cost of items leaving the ASL.

TABLE 14

MODEL COMPARISON

	PRESENT	PROPOSED
Number of Items	3,827	5,699
Accommodation	.74	.80
Satisfaction	.98	.96
Availability	.72	.76
Turbulence	.13	.19
$RO	2,277,993	1,746,669
$ Inventory	768,478	754,969
Operating Cost	631,333	507,240
Operating Cost		
Holding	569,498	436,667
Ordering	151	108
Variable Removal	29,614	22,707
Fixed Removal	2,488	3,704
Maintain ASL	29,582	44,058
TOTAL	$631,333	$507,240

BIBLIOGRAPHY

1 AMCPA-S letter (3rd Ind), subject: IRO Project No. 235: Recomputation of Economic Order Quantity Tables for Depot Use, dated 20 Jan 75.

2 AR 710-2, "Materiel Management for Using Units, Support Units and Installations," 1 Oct 71, Change 1, 15 Jun 73.

3 Chern, Chung Mei, "An Empirical Approach to Variable Safety Levels for Army Overseas Theatres," AMC Inventory Research Office (ALMC), Frankford Arsenal, Phila., Pa., May 1972, AD 745397.

4 Deemer, R. L., "Inventory Costs at AMC Depots," AMC Inventory Research Office (ALMC), Frankford Arsenal, Phila., Pa., Dec 75, AD A021717.

5 Deemer, R. L., A. J. Kaplan and W. K. Kruse, "Application of Negative Binomial Probability to Inventory Control," AMC Inventory Research Office (ALMC), Frankford Arsenal, Phila., Pa., Dec 74, AD A003225.

6 Deemer, R. L. and W. K. Kruse, "Evaluation of Several VSL/EOQ Models," AMC Inventory Research Office (ALMC), Frankford Arsenal, Phila., Pa., May 1974, AD 781948.

7 Defense Supply Agency, "Compendium of Inventory Control Point Management Information, Volume I, Management Data," Alexandria, VA, Nov 1974.

8 DoDI 4140.39, "Procurement Cycles and Safety Levels of Supply for Secondary Items," July 1970.

9 Hadley, G. and T. M. Whitin, "Analysis of Inventory Systems," Prentice Hall, Englewood Cliff, NJ, 1963.

10 Kaplan, A. J., "Estimation of Demand Variability Parameters," AMC Inventory Research Office (ALMC), Frankford Arsenal, Phila., PA, May 1974, AD 781942.

11 Kruse, W. K., "Forecasting Order and Ship Time for CONUS Depots," DRC Inventory Research Office, US Custom House, Phila., PA, June 77, AD A041691.

12 Orr, D., "Accommodation and Turbulence Projection Using One and Two Year Demand Base," AMC Inventory Research Office (ALMC), Frankford Arsenal, Phila., PA, Dec 1971, AD 737716.

13 Orr, D. and A. J. Kaplan, "The Economic Stockage Model," AMC Inventory Research Office (ALMC), Frankford Arsenal, Phila., PA, June 1971, AD 727694.

14 Parzen, Emmanuel, "Stochastic Processes," Holden-Day, Inc., San Francisco, 1962.

APPENDIX A

NICP REQUISITION PROCESSING COST

The Defense Supply Agency, DSA (now called Defense Logistics Agency) did a major study on Inventory Control Point (ICP) management information data [7]. One aspect of the study was to break down the costs of the requisition processing at the ICPs for the various Services. The cost of processing the requisitions at the ICPs was identified by the following work elements: receiving, recording and processing materiel requisition documents, maintaining requisition files; technical data research; providing status information on requisitions; and liaison operations with using activities. These functions resulted in the following breakout by Army Commodity Command:

COMMODITY COMMAND	COST OF PROCESSING REQUISITIONS (THOUSANDS)	NUMBER PROCESSED (THOUSANDS)	COST/ REQUISITION
ARRCOM	657	475	$1.38
AVSCOM	1,171	586	2.00
ECOM	3,262	480	6.80
MIRCOM	831	147	5.65
TARCOM	814	1,093	.74
TROSCOM	1,026	127	8.08
TOTAL	7,761	2,908	
		AVERAGE COST PER REQUISITION	$2.67

APPENDIX B

REORDER POINT MODEL

The reorder point (ROP) computation is based on the DoDI 4140.39 model [8] which finds the ROP that minimizes the total annual variable cost, sum of holding, ordering and shortage costs, for all items. That is,

$$\min \left\{ \sum_{\text{ITEMS}} \left[\left(R_i + \frac{Q_i}{2}\right) HU_i + O \frac{D_i}{Q_i} + \frac{\lambda}{S_i Q_i} \int_{R_i}^{\infty} (x - R_i) [F(x+Q_i; L_i) - F(x; L_i)] [dx] \right\} \right. \tag{B-1}$$

where

R_i = reorder point for item i

Q_i = operating level for item i

H = the yearly holding cost rate

U_i = unit price for item i

O = the order cost

D_i = average yearly demand (units) for item i

λ = implied requisition short cost

S_i = average requisition size for item i

L_i = lead time for item i

$F(x;t)$ = probability of having x or fewer demands in time t

To solve (B-1), it is necessary to have; a probability distribution $F(.;.)$, knowledge about the mean demand and knowledge of the variance about the mean demand. The Army wholesale level of supply uses the negative binomial probability distribution for slower moving items (less than 20 demands per year) and also for insurance items, i.e., those items which

are not expected to fail at all. Also, Chern [3] used this probability distribution in work for Army overseas theatres. Hence, the probability distribution used in the reorder point calculations is the negative binomial distribution.

The DARCOM depot level of supply only keeps a one year data history; hence, a one year average of the mean demand is used in the calculations of the reorder point.

A method of calculating the item variance about the mean demand is to approximate the variance of the item by looking at the variance of many similar items. Kaplan [10] found this method to be the best method at the wholesale level of supply. Likewise, Chern [3] found it to be applicable at the Army overseas inventory centers. Thus, the catalog method of computing variance is used in the calculation of the reorder point.

Chern [3] showed that the variance of demand in the lead time was mostly influenced by the variance of demand. However, the variability of the OST did have some influence in the reorder point calculations. Chern used the Parzen formula [14] for the variance of a conditional random variable. Reduced to inventory terms, Parzen's expression becomes:

$$VAR(OSTD) = E[Var(D|\overline{OST})] + Var\ [E(D|\overline{OST})]$$

$$VAR(OSTD) = E(OST)\ Var(D|\overline{OST}) + Var(OST)\ E^2(D) \tag{B-2}$$

which says the total variance of OST demand [VAR(OSTD)] is equal to the expected value of the OST [E(OST)] times the variance of demand during the expected OST [$Var(D|\overline{OST}]$ plus the variance of the OST [Var(OST)] times the square of the expected demand rate [$E^2(D)$]. This is the variance of lead time demand used in one method for the calculation of the reorder point.

The expression (B-2) is the expression for the variance of a conditional random variable. Hadley and Whitin [9] develop another expression for a DOD type model for stockastic lead times. It is of the form:

$$TC(R,Q) = \int_0^{\infty} TC(R,Q|t)\ g(t)dt \tag{B-3}$$

where TC(R,Q | t) is the total annual variable cost as a function of the reorder point, R, the operating level, Q, for the lead time, t. g(t) is the density function of the lead time, t. This is an exact model as long as there is never more than a single order outstanding. If more than one order is outstanding, then it is not true that the lead times can be considered as independent random variables since to be independent the orders would have to cross, i.e., the first order placed could be received by the customer after the second order placed is received. In practice, however, it is usually true that orders are received in the sequence in which they are placed. In general, there is no easy way to handle dependent lead times. However, as an approximation to the exact case, it can be said that in practice orders are placed sufficiently far enough apart so that there is essentially no interaction between any two orders, i.e., they are essentially independent.

To implement (B-3) Kruse [11] developed an empirical histogram of lead time probabilities, h(t). Then the Hadley and Whitin model (B-3) becomes

$$TC(R,Q) = \sum_{t=o}^{\infty} \left\{ HU[R(t) + \frac{Q}{2}] + O\,\frac{D}{Q} + \lambda\, \frac{B[R(t),Q]}{S} \right\} h(t)$$

Taking differences yields

$$TC(R(t)) - TC(R(t)-1) = \sum_{t=o}^{\infty} \left\{ HU + \frac{\lambda}{S}\, [B(R(t) - B(R(t) - 1)] \right\} h(t)$$

The optimum R is the largest R such that the difference is non-positive, i.e.,

$$\sum_{t=o}^{\infty} \left\{ HU + \frac{\lambda}{S}\, [B(R(t)) - B(R(t) - 1)] \right\} h(t) \leq 0$$

or

$$\frac{H(U)(S)}{\lambda} \leq \sum_{t=o}^{\infty} [1 - \alpha\, (R(t))]\, h(t) \qquad \text{(B-4)}$$

where

$$B(R(t) - 1) - B(R(t) = 1 - \alpha\ (R(t))^{*}$$

$\alpha\ (R(t))$ is the expected availability for the reorder point, $R(t)$

and remembering $\sum_{t=o}^{\infty} h(t) = 1.$

The optimum R(t) is thus achieved by weighting the expected availability for each OST by the probability of observing the actual OST, t, summed over all possible OST values (equation B-4).

The reorder point computations were initially computed using six forecasted OST values with the 12 possible OST values for each forecast (see Figure 1, Section 2.4), a λ value of $1200, H equal to .25 and the OL as shown in Section 1.3.

Preliminary analysis showed the optimum reorder point gave values that were quite large. Therefore, a constraint was sought to limit the safety level. Table B-1 shows the impact of several sets of constraints on the maximum safety level. These results were obtained using only one OST value, 30 days, for all items. A frequency row is for all the items with that frequency of requisition, regardless of dollar value of annual demand.

All the computations assumed a minimum safety level of zero. The columns within a constraint variation are the safety level in months of supply and the theoretical availability achieved with that safety level. The availability is the percent of requisitions which are filled from stock on-hand. The optimum results shown in the table are constrained optimum values. These safety levels are constrained so that the availability does not exceed .99. The 3 month maximum results indicate the constraint is imposed on almost all items. The two standard deviation maximum (2σ) of lead time demand gives results which are comparable to the optimum values, i.e., high safety levels for low frequency items. The 5 month constraint looks attractive in that the constraint is active for slow moving items. The 5 month maximum

*See [5], Appendix II for derivation of this step.

TABLE B-1

SAFETY LEVEL

	Optimum		3 Mos Max		5 Mos Max		2σ Max	
Frequency	SL(Mos)	Avail	SL(Mos)	Avail	SL(Mos)	Avail	SL(Mos)	Avail
1	13.43	.984	3	.976	5	.978	10.46	.982
2	11.41	.983	3	.970	5	.974	8.25	.979
3	10.73	.983	3	.969	5	.974	7.39	.979
4	10.95	.985	3	.969	5	.974	6.91	.979
5	6.93	.980	3	.965	5	.974	5.68	.976
6	6.07	.979	3	.966	5	.975	5.43	.977
7	5.64	.978	3	.966	5	.976	5.24	.977
8	4.91	.977	3	.967	5	.977	5.11	.977
9	4.45	.979	3	.971	5	.982	4.48	.979
10	3.38	.980	3	.978	4.77	.988	3.77	.983
11	2.27	.974	3	.980	3.62	.983	3.66	.984
12	5.89	.987	3	.974	5	.984	4.21	.981
13	3.16	.983	3	.982	4.82	.990	3.50	.985
14	3.23	.978	3	.975	4.50	.986	3.43	.979
15	3.26	.978	3	.976	4.54	.987	3.38	.979
17.75	2.50	.984	3	.988	3.36	.990	3.03	.988
22.98	2.38	.979	3	.985	3.19	.986	2.86	.983
27.72	2.44	.981	3	.987	3.49	.990	2.75	.985
33.15	2.01	.966	3	.982	2.69	.978	2.53	.976
37.57	2.00	.982	2.96	.990	2.68	.990	2.47	.987
42.63	2.16	.978	3	.988	2.77	.986	2.43	.982
48.33	.88	.886	3	.975	1.61	.932	1.63	.933
52.88	2.45	.984	3	.990	3.14	.991	2.34	.983
57.00	1.45	.958	3	.987	1.89	.970	1.91	.970
78.50	1.08	.916	3	.986	1.97	.963	1.99	.964

safety level was chosen as the constraint to be used with the table development.

The final implementable version of the computations are tables. This necessitates some approximation to the optimum results. Tables B-2 through B-7 show fairly accurate tables. However, a further approximation is desired, i.e., fewer numbers. Visual inspection of the tables was utilized to group cells with similar results. The median of the groupings thus accomplished produces the final results.

TABLE B-4
SAFETY LEVELS

OST = 45.00 λ = 1200

$AYD (00)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	60
.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9
3	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	5.0	5.0	4.9	4.9	4.9	4.9
4	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0	4.9
5	0.0	3.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	5.0	5.0	4.9	4.9	4.9	4.9
6	0.0	.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
7	0.0	0.0	4.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
8	0.0	.1	2.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	4.9	4.9	4.9	5.0	5.0	4.9
9	0.0	0.0	1.1	2.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	4.9
10	0.0	0.0	.1	3.9	5.0	5.0	5.0	5.0	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9
30	0.0	0.0	0.0	0.0	2.4	2.3	4.1	3.2	3.4	5.0	3.9	5.0	4.8	4.8	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0
50	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	1.0	2.0	1.6	2.8	2.1	2.3	2.8	2.4	3.6	4.0	3.6	3.5	4.0	4.4	4.0	4.3	3.7
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.4	.6	.9	1.1	1.2	1.2	2.2	2.3	2.4	2.4	2.5	3.4	3.6	3.7	4.0	3.1
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.5	.6	.8	1.1	1.6	1.8	1.9	2.1	2.3	2.4	2.6	2.7	2.5
150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	0.0	0.0	.4	.9	1.2	1.3	1.6	1.7	1.8	2.0	2.1	2.3
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.4	.4	.4	1.0	1.1	1.3	1.5	1.6	1.6	1.7
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.3	.4	.6
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Annual Frequency

TABLE B-3

SAFETY LEVELS

OST =50.00 λ = 1200

$AYD (00)	1	2	3	4	5	6	7	8	9	10	11	Annual Frequency 12	13	14	15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	60
.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	5.0
.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0
.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0
.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	5.0
.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0
.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0
.9	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	5.0	5.0	5.0	5.0	5.0	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	5.0
1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0
2	1.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	5.0	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
3	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	5.0	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
4	0.0	3.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
5	0.0	1.5	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
6	0.0	0.0	3.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
7	0.0	0.0	2.5	4.8	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	4.9	5.0	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
8	0.0	0.0	.8	3.1	4.4	4.9	5.0	5.0	4.9	4.9	4.9	4.9	4.9	5.0	4.9	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
9	0.0	0.0	0.0	.9	3.6	4.8	4.9	5.0	4.6	4.7	4.7	4.8	4.9	4.9	4.9	4.5	4.8	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
10	0.0	0.0	0.0	2.5	3.7	4.4	4.6	4.9	3.7	4.6	4.9	5.0	5.0	4.9	4.9	4.9	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9	4.9
30	0.0	0.0	0.0	0.0	1.3	1.3	2.7	2.2	2.4	4.5	2.5	4.2	3.4	3.5	4.3	3.7	4.2	4.4	3.9	4.3	3.3	3.8	4.2	4.3	3.8
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.5	1.3	1.0	1.9	1.3	1.7	1.9	1.7	2.5	2.7	2.4	2.2	2.5	2.6	2.6	2.7	2.3
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.3	.4	.7	.8	.8	1.6	1.6	1.7	1.7	1.7	2.3	2.4	2.4	2.5	1.9
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.3	.4	.7	1.1	1.3	1.5	1.5	1.6	1.6	1.7	1.8	1.6
150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.6	.8	1.0	1.2	1.2	1.3	1.4	1.5	1.7
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.4	.4	.4	.7	.8	1.0	1.1	1.1	1.2	1.1
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.2	.5
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE B-2

SAFETY LEVELS

OST = 15.00

λ = 1200

Annual Frequency

SAYD (00)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	60
.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
.2	5.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0
.3	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	4.6
.4	5.0	5.0	5.0	4.9	4.9	4.9	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0
.5	5.0	5.0	5.0	4.9	4.9	5.0	5.0	4.9	4.9	4.9	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	4.6
.6	2.5	5.0	5.0	4.9	4.9	4.9	5.0	4.9	4.9	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	4.9
.7	2.5	5.0	5.0	5.0	4.9	4.9	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	4.6
.8	0.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	3.1	5.0	5.0	5.0	5.0	5.0	3.8
.9	.9	5.0	5.0	5.0	5.0	4.9	4.9	5.0	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.6	4.7	4.8	5.0	5.0	5.0	3.6
1	0.0	5.0	5.0	4.9	5.0	5.0	5.0	4.9	4.9	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.4	4.5	4.7	4.8	4.9	5.0	3.6
2	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	3.1	4.3	4.4	4.5	5.0	5.0	3.8
3	0.0	.3	3.7	4.9	5.0	5.0	5.0	4.9	4.3	4.5	4.3	4.3	4.1	4.1	4.0	3.4	3.2	3.2	2.7	2.4	2.6	2.7	2.7	2.7	2.9
4	0.0	0.0	1.7	4.0	4.7	4.9	5.0	5.0	4.2	4.4	4.3	4.7	4.5	4.2	4.1	3.6	3.5	3.2	2.9	2.8	2.9	3.6	3.7	3.4	3.0
5	0.0	0.0	.7	1.9	3.6	4.3	4.6	4.4	3.8	3.7	3.7	3.6	3.7	3.7	3.4	3.1	3.1	2.9	2.6	2.1	2.1	3.1	3.1	3.1	3.1
6	0.0	0.0	0.0	1.2	2.6	3.2	3.7	3.5	3.1	3.3	3.3	3.3	3.1	3.2	3.3	2.8	2.9	2.6	2.3	2.3	2.0	2.0	2.0	2.0	1.6
7	0.0	0.0	0.0	.6	1.5	2.4	2.7	2.9	2.5	2.9	2.5	2.3	2.9	2.8	3.0	2.4	2.5	2.4	2.2	2.3	2.5	2.4	2.0	2.0	2.0
8	0.0	0.0	0.0	0.0	.7	1.1	2.3	2.6	2.3	2.6	2.6	2.7	2.5	2.6	2.7	2.4	2.4	2.4	2.1	2.1	2.2	2.1	2.1	2.2	1.7
9	0.0	0.0	0.0	0.0	.4	1.4	1.6	2.5	2.1	2.1	2.3	2.3	2.3	2.4	2.4	2.1	2.1	2.1	1.9	2.0	1.9	2.0	1.9	2.1	1.6
10	0.0	0.0	0.0	.1	.5	1.3	1.3	2.0	1.3	2.0	2.5	2.6	2.6	2.5	2.6	2.6	2.5	2.3	2.3	2.2	2.3	2.3	2.3	2.5	1.8
30	0.0	0.0	0.0	0.0	0.0	0.0	.3	.2	.5	2.2	1.2	2.1	1.4	1.5	2.1	1.8	2.0	2.0	1.7	1.9	1.5	1.5	1.7	1.6	1.5
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.4	.1	.5	.5	.6	1.1	1.2	1.0	.9	1.1	1.1	1.2	1.2	1.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.5	.6	.6	.8	.7	1.0	1.1	1.2	1.2	.8
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	.4	.5	.5	.6	.7	.7	.7	.7
150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.3	.5	.5	.6	.6	.7	.7
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.1	.1	.2	.3	.3	.5	.5	.5
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE B-5

SAFETY LEVELS

OST = 50.00 λ = 1200

$AYD (00)	Annual Frequency 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	60
.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
.2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	5.0	5.0	5.0	5.0	4.9
.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	5.0	5.0	4.9
.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	5.0	5.0	5.0	5.0	4.9
.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	5.0	5.0	4.9
.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	5.0	5.0	5.0	5.0	4.9
.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	5.0	5.0	4.9
.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	5.0	5.0	5.0	5.0	4.9
1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	5.0	5.0	5.0	5.0	4.9
2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
3	1.2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
4	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	5.0	5.0	5.0
5	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
6	0.0	2.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
7	0.0	1.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
8	0.0	.6	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	5.0	5.0
9	0.0	.6	2.6	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	5.0	5.0	5.0
10	0.0	0.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	5.0	4.9	4.9
30	0.0	0.0	.1	.2	3.6	3.4	5.0	4.3	4.3	5.0	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	5.0	4.9	4.9
50	0.0	0.0	0.0	0.0	.1	.2	.7	1.0	1.7	2.8	2.3	3.6	2.8	3.0	3.6	3.1	4.4	4.9	4.4	4.2	4.9	4.9	4.9	4.9	4.5
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	.6	.8	1.1	1.4	1.6	1.7	1.7	2.8	3.0	3.1	3.1	3.1	4.2	4.4	4.7	4.9	3.8
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.6	.9	1.1	1.2	1.6	2.1	2.5	2.5	2.7	2.9	3.2	3.4	3.4	3.2
150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	0.0	0.0	.1	.2	.7	1.2	1.6	1.7	2.0	2.2	2.4	2.5	2.7	2.9
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.6	.6	.6	1.4	1.5	1.7	1.8	2.0	2.2	2.1
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.4	.5	.6	.9
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE B-6

SAFETY LEVELS

OST = 75. [illegible]

λ = 1200

Annual Frequency

$AYD (00)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	60
.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
.2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9
.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	4.9	4.9	4.9
.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9
.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9
.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9
.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9
.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	5.0	4.9	4.9	4.9
.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	4.9	4.9	4.9
1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9
2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	4.9	5.0
3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	5.0	4.9	4.9	5.0
4	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9
5	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9
6	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9
7	0.0	4.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9
8	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
9	0.0	1.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9
10	0.0	0.0	5.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
30	0.0	0.0	.7	1.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
50	0.0	0.0	0.0	0.0	.2	1.5	1.9	2.3	2.6	4.0	3.3	5.0	4.1	4.3	4.9	4.1	5.0	5.0	5.0	4.9	5.0	5.0	5.0	5.0	4.9
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.4	1.6	1.9	2.3	2.5	2.7	2.7	3.8	4.1	4.2	4.0	4.1	4.9	4.9	5.0	5.0	4.4
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	.6	1.4	1.6	1.9	2.2	2.4	3.0	3.5	3.4	3.6	3.9	4.1	4.5	4.4	3.9
150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	.4	.4	.5	.6	1.2	1.4	2.3	2.5	2.7	3.0	3.2	3.4	3.5	3.8
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	1.1	1.1	1.1	2.0	2.2	2.5	2.7	2.8	3.0	2.8
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	.6	.8	1.0	1.2	1.4
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.5
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE B-7

OST = 90.00 SAFETY LEVELS λ = 1200

Annual Frequency

$AYD (00)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	∞
.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
.2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	5.0	4.9	4.9	4.9
.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	5.0	5.0
.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9
.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	4.9	4.9	4.9	4.9
.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9
.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9
.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9
.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	5.0	5.0
1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9
2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
4	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
5	.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
6	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
7	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
8	0.0	4.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
9	0.0	2.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
10	0.0	0.0	4.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
30	0.0	0.0	1.5	2.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
50	0.0	0.0	0.0	0.0	.6	2.0	2.6	3.1	3.4	4.9	4.1	5.0	5.0	5.0	5.0	4.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.9	2.1	2.5	2.9	3.2	3.5	3.5	4.6	4.9	5.0	4.8	4.9	5.0	5.0	5.0	5.0	4.9
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.5	.6	.9	1.8	2.3	2.5	2.8	3.1	3.7	4.3	4.1	4.5	4.8	5.0	5.0	5.0	4.5
150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.5	.7	.6	.8	1.0	1.6	2.4	2.9	3.1	3.4	3.6	4.0	4.1	4.3	4.7
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	1.4	1.4	1.4	2.4	2.8	3.0	3.3	3.5	3.8	3.4
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	.6	.8	1.1	1.3	1.6	1.7
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.7
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX C

ECONOMIC STOCKAGE MODEL

The basic economic stockage model was developed by Orr and Kaplan [13]. Changes were necessary to the basic model for application to the DARCOM depot level of supply. The basic idea of the economic stockage model is to find the break-even point of stocking an item versus not stocking an item. The addition-retention (A-R) criteria which are chosen from the model are the A-R criteria which yield the lowest total cost.

The theoretical cost of any A-R set depends on the cost of entering or leaving the ASL as well as on the probability associated with these actions. The cost transition matrix is

		End	
		On	Off
Start	On	r_{11}	r_{12}
	Off	r_{21}	r_{22}

where

r_{11} = cost of restocking = $F + C_H + C_O + UM\,(C_B W + C_S)$

r_{21} = cost of stocking = $r_{11} + C_A$

r_{22} = cost of not stocking = $M(C_B L + C_N)$

r_{12} = cost of removal = $C_R + r_{22}$

and

F = fixed cost of stocking an item ($7.73)

C_H = holding cost per year = (ROP + Q/2)H(P)

ROP = reorder point

Q = Operating Level

H = holding cost rate per year (.25)

P = unit price

C_O = order cost per year = O D/Q

O = order cost per order ($21)

D = average yearly demand

U = unavailability = fraction of all requisitions unable to be filled from stock on-hand

M = mean number of requisitions per year

C_B = penalty cost per requisition per year

W = average wait for stocked items which are on backorder

C_S = extra processing cost per requisition for items stocked but not available ($.01)

C_A = cost of adding an item to the ASL ($.01)

L = order-and-ship time

C_N = processing cost per requisition for items not stocked ($21)

C_R = fixed removal cost ($5)

The assumption is made that the number of requisitions is Poisson distributed with unknown mean. For a given mean requisition frequency, M, the probability transition matrix looks like:

$$\begin{array}{ll|ll} & & \multicolumn{2}{c}{\underline{\text{End}}} \\ & & \text{On} & \text{Off} \\ \hline \underline{\text{Start}} & \text{On} & P_R & 1-P_R \\ & \text{Off} & P_A & 1-P_A \end{array} \equiv \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix}$$

where P_R = prob (item on ASL and stays on) =

$$P(\# \text{ requisitions} \geq R; M)$$

P_A = prob (item off ASL and added to it) =

$$P(\# \text{ requisitions} \geq A; M)$$

The cost for any A-R set for state i is:

$$V_i(M,A,R) = \sum_{j=1}^{2} [r_{ij}p_{ij} + \alpha\, V_j(M,A,R)\; p_{ij}]$$

where the first term is the expected one period transitory cost from state i and the second term represents the discounted expected cost of starting in state j. This expression is solved for $V_i(M,A,R)$ and then each of these costs is weighted by the probability of that particular frequency of demand. Thus,

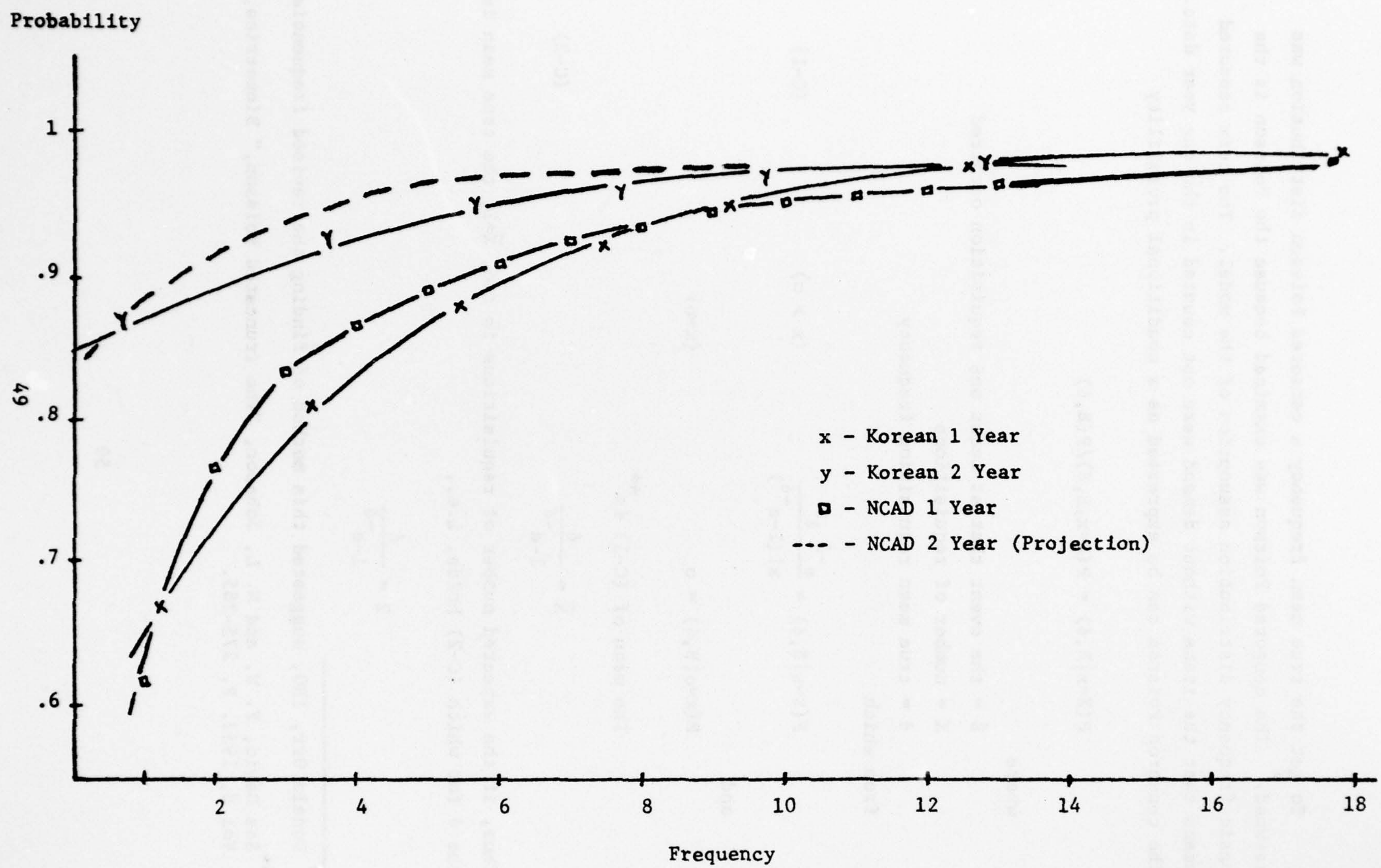
$$V(A,R) = \sum_m V(m,A,R)g(m)$$

The g(m) represents the probability density of an item with mean requisition frequency m. The probability g(•) was based on the New Cumberland Army Depot (NCAD) data.

The NCAD data was for only one year. However, Orr [12] pointed out that the use of one year of observed requisition frequencies gave a misleading picture of the frequency distribution, g(•). A method for adjusting the observed distribution was desired. There were two elements which had to be corrected. They were: the probability of obtaining a certain frequency; and the frequency itself.

Based on Orr's work it was deemed sufficient to correct the probabilities by extrapolating to those which would have been observed had two years of data been available. This extrapolation was accomplished by a graphical technique. The assumption was made that the one and two year probabilities of Orr's Korean Inventory Control Center, MATCAT-H data, [12], had the same general relationship to each other as would the NCAD one and two year data. Hence, the Korean one and two year histories were plotted, Figure C-1. Over the one year Korean curve, the one year NCAD curve was plotted. This general relationship of Korean one year data to NCAD one year data was then approximated and plotted against the Korean two year curve to yield a hypothetical two year NCAD curve. From this hypothetical curve, the probabilities of certain frequencies can be approximated.

FIGURE C-1



Probability
1
.9
.8
.7
.6
2
4
6
8
10
12
14
16
18
Frequency
x - Korean 1 Year
y - Korean 2 Year
▫ - NCAD 1 Year
--- - NCAD 2 Year (Projection)

To get the true mean frequency a censored Poisson distribution was assumed.* The censored Poisson was examined because the Poisson is the basic frequency distribution assumption of the model. The term censored means that the items without demand were not counted in the one year data. The censored Poisson can be expressed as a conditional probability

$$P(X=x|B,\delta) = P(X=x,B,\delta)/P(B,\delta)$$

where

B = the event that at least one requisition occurred

X = number of requisitions

δ = true mean requisition frequency

from which

$$P(X=x|B,\delta) = \frac{e^{-\delta}\delta^{x}}{x!(1-e^{-\delta})} \qquad (x > o) \qquad \text{(C-1)}$$

and

$$P(x=o|B,\delta) = o \qquad (x=o)$$

The mean of (C-1) is**

$$\overline{X} = \frac{\delta}{1-e^{-\delta}} \qquad \text{(C-2)}$$

Thus, if the expected number of requisitions is two, $\overline{X}=2$, the true mean is the δ for which (C-2) holds, i.e.,

$$2 = \frac{\delta}{1-e^{-\delta}}$$

---

* Donald Orr, IRO, suggested this method of finding the revised frequencies.

** See David, F. N. and N. L. Johnson, "The Truncated Poisson," Biometrics, Vol 8, 1952, P. 275-285.

Solving the above yields $\delta = 1.62$.

(C-2) cannot be solved for $\overline{X}=1$ since the censored Poisson distribution is assumed, i.e., items without demand are not counted ($\overline{X}=1 \Rightarrow \delta = 1-e^{-\delta} \Rightarrow \delta=0$).

The technique used to get the revised two year probability for $\overline{X}=1$ is again based on an assumption about the Korean data. The assumption is that the ratio between the average yearly demand frequencies of the Korean data (two year frequencies to one year frequencies) is approximately the same as the NCAD data. The method* looks at the ratio mentioned for both the Korean data and the NCAD data. Algebraically it is

$$\frac{xf'(1) + yf'(2)}{1f(1) + 2f(2)} = \frac{k_2}{k_1} \qquad \text{(C-3)}$$

where

x = revised demand frequency of one requisition

y = revised demand frequency of two requisitions

$f'(\cdot)$ = revised requisition probability

$f(\cdot)$ = original one year requisition probability

1 and 2 = demand frequencies (1 or 2 requisitions per year)

k_2 = Korean two year frequency (average of 0-2 requisitions per year)

k_1 = Korean one year frequency (average of 0-2 requisitions per year)

The numerators represent the two year average yearly demand frequency. The numerator on the left side represents the average frequency of the hypothetical NCAD data for two years for requisition frequencies of one and two (zero requisitions were not included in the data). The denominators represent the one year average annual demand frequency. The denominator on the left side represents the one year NCAD data for annual demand frequency of one and two.

---

*Alan Kaplan, IRO, suggested this method of calculating the revised frequency.

Using (C-2), (C-3) becomes

$$x = \left[\frac{.675[.6179 + 2\ (.1517)]}{1.25} - 1.62\ (.048)\right] \frac{1}{.862} = .487$$

Table (C-1) shows the one year empirical values and the revised two year values using the methods just described.

Orr and Kaplan [13] made the assumption that all items start off the ASL. For initial provisioning, this is a valid assumption. However, since the Poisson probability distribution is the distribution of the number of requisitions, if the mean is not too big, say 8, the probability of getting zero demand is very small, .0003. Hence, if an item started off the ASL and had a mean number of requisitions of 8, there would be a very small chance of not seeing any demand for this item. As a result the A-R criteria would tend to be lower values to allow such items some chance of getting on the ASL. Therefore, the ASL computations for this work are accomplished by assuming the item starts on the ASL.

The penalty cost per requisition, C_B, is the cost of not having stock available when a request is made. The penalty cost does not recognize the length of time the customer must wait for the item. However, the penalty cost associated with the safety level computation is weighted by the time the requisitioner waits till the request is filled. The wait for the request to be filled is over and above the wait due to normal delay when the item is available from stock on-hand. To make the penalty cost of the stockage policy consistent with the penalty cost of the safety level calculations, consideration is given to time on backorder for items that are stocked but not available when requested. This is done by weighting the penalty cost by the average theoretical wait. The wait is given by

$$W = \frac{E(RS)}{E(R)}$$

where

$E(RS)$ = expected requisitions short

$E(R)$ = expected number of requisitions per year backordered

TABLE C-1

NCAD EMPIRICAL AND PROJECTED FREQUENCIES/PROBABILITIES

1 Year (Empirical)		2 Year (Projected)	
Frequency	Probability	Frequency	Probability
1	.6179	.487	.862
2	.1517	1.62	.048
3	.0609	2.38	.028
4	.0361	3.94	.019
5	.0219	4.94	.010
6	.0171	6	.005
7	.0163	7	.006
8	.0106	8	.002
9	.0089	9	.001
10	.0070	10	.001
11	.0060	11	.001
12	.0042	12	.001
13	.0054	13	.001
14	.0049	14	.001
15	.0033	15	.001
17.74	.0113	17.74	.003
23.11	.0052	23.11	.001
27.82	.0042	27.82	.001
33.29	.0013	33.29	.001
37.57	.0020	37.57	.001
42.60	.0010	42.60	.001
48.75	.0004	48.75	.001
52.75	.0008	52.75	.001
57.00	.0004	57.00	.001
85.62	.0012	85.62	.002

This adjustment is only necessary for items which are stocked since non-stocked items always have to wait the OST.

An approximation is sought for the A-R criteria. A priori it is not known how to divide the annual dollar demand categories. Hence, many classes were initially examined to get some idea as to where further approximation could be made. Table C-2 shows the most accurate approximation examined.

This table shows where further approximations could be made. The final results are the breakdown of this first approximation consistent . for all six OST values. The final table is cut off at an annual requisition frequency of 12 because items which are requested once a month should certainly be considered for stockage.*

---

*US Army Quartermaster School work by MAJ Walter Bawell reinforced this thought. He found that 80% of the items with 12 or more demands should be stocked at a Direct Support Unit.

TABLE C-2

STOCKAGE POLICY

$AYD	OST=15		OST=30		OST=45		OST=60		OST=75		OST=90	
≤ 10	2	1	2	1	2	1	2	1	2	1	2	1
20	2	1	2	1	2	1	2	1	2	1	2	1
30	2	1	2	1	2	1	2	1	2	1	2	1
40	2	1	2	1	2	1	2	1	2	1	2	1
50	2	1	2	1	2	1	2	1	2	1	2	1
60	2	1	2	1	2	1	2	1	2	1	2	1
70	3	1	2	1	2	1	2	1	2	1	2	1
80	3	1	2	1	2	1	2	1	2	1	2	1
90	3	1	2	1	2	1	2	1	2	1	2	1
100	3	1	2	1	2	1	2	1	2	1	2	1
200	3	1	2	1	2	1	2	1	2	1	2	1
300	3	1	3	1	2	1	2	1	2	1	2	1
400	4	2	3	1	2	1	2	1	2	1	2	1
500	4	2	3	1	3	1	2	1	2	1	2	1
600	4	2	3	1	3	1	2	1	2	1	2	1
700	4	2	3	1	3	1	3	1	2	1	2	1
800	4	2	4	1	3	1	3	1	2	1	2	1
900	5	2	4	1	3	1	3	1	3	1	2	1
1000	5	2	4	2	3	1	3	1	3	1	3	1
3000	5	3	4	2	4	2	4	1	3	1	3	1
5000	6	3	4	3	4	2	4	2	4	2	4	2
8000	9	5	7	3	6	3	6	3	5	3	5	2
10000	11	6	8	4	6	3	6	3	6	3	6	3
15000	12	7	11	5	8	4	7	4	7	4	7	3
20000	13	8	12	6	10	5	9	5	9	4	8	4
50000	21	11	17	9	16	8	15	8	13	8	13	7
100000	23	14	23	12	20	11	20	11	19	11	19	11
> 100000	51	32	48	29	46	27	46	26	45	25	45	25

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